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(54) **HEAT EXCHANGER WITH SUBCOOLING CIRCUIT**

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F24F 13/22 (2006.01)
F24F 1/00 (2011.01)

(52) **U.S. Cl.**

CPC ***F24F 13/222*** (2013.01); ***F24F 1/0007*** (2013.01); *Y10T 29/4935* (2015.01)

(58) **Field of Classification Search**

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USPC 62/285, 291, 333, 513, 524, 526
See application file for complete search history.

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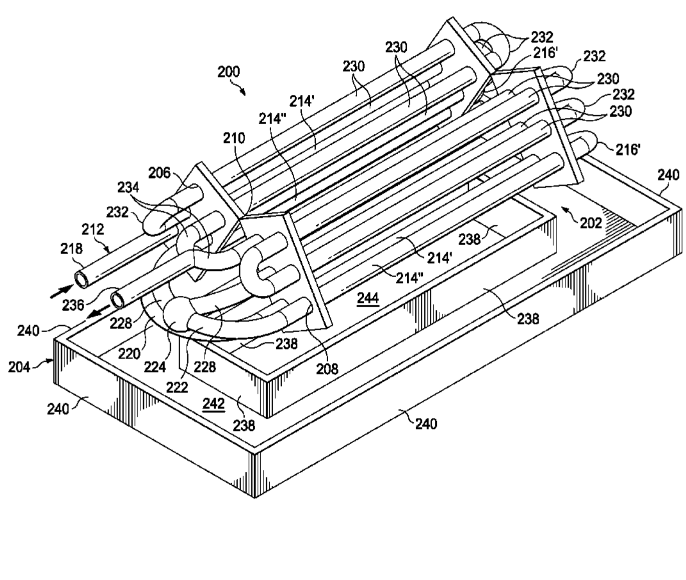
(57) **ABSTRACT**

An air handling unit has a blower configured to selectively move air from an air inlet of the air handling unit to an air outlet of the air handling unit along an airflow direction extending from the blower to the air outlet, a heat exchanger disposed within the air handling unit between the inlet and the outlet, the heat exchanger has a thermal conductor, an evaporator tube thermally conductively joined to the thermal conductor, and a subcooler tube thermally conductively joined to the thermal conductor. An expansion device provides fluid communication between the evaporator tube and the subcooler tube and a drain pan disposed within the air handling unit upstream relative to the at least one subcooler tube and positioned in a geometrical footprint of at least a portion of the drain pan as the drain pan is viewed from an upstream position in the airflow direction.

15 Claims, 5 Drawing Sheets



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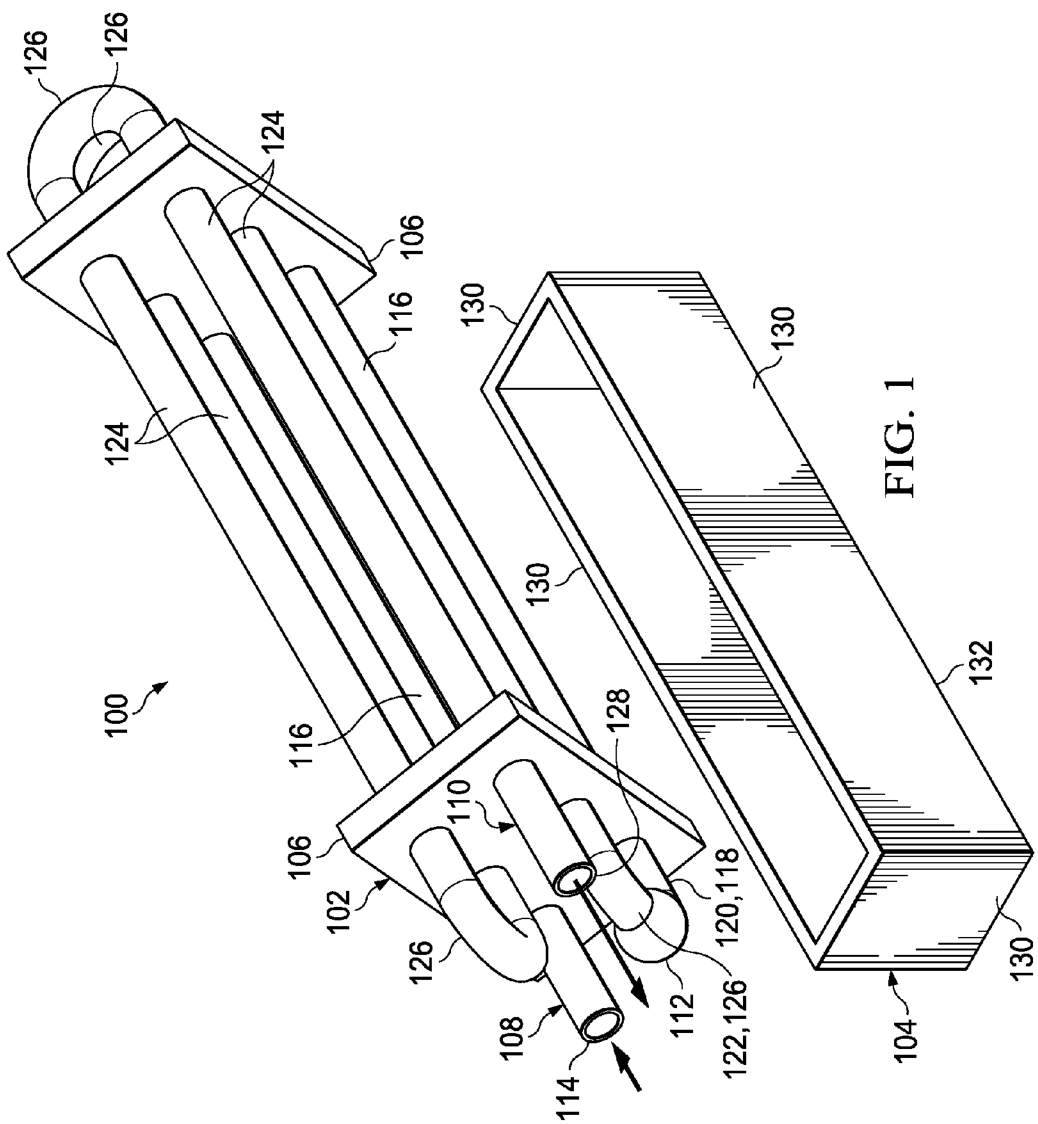
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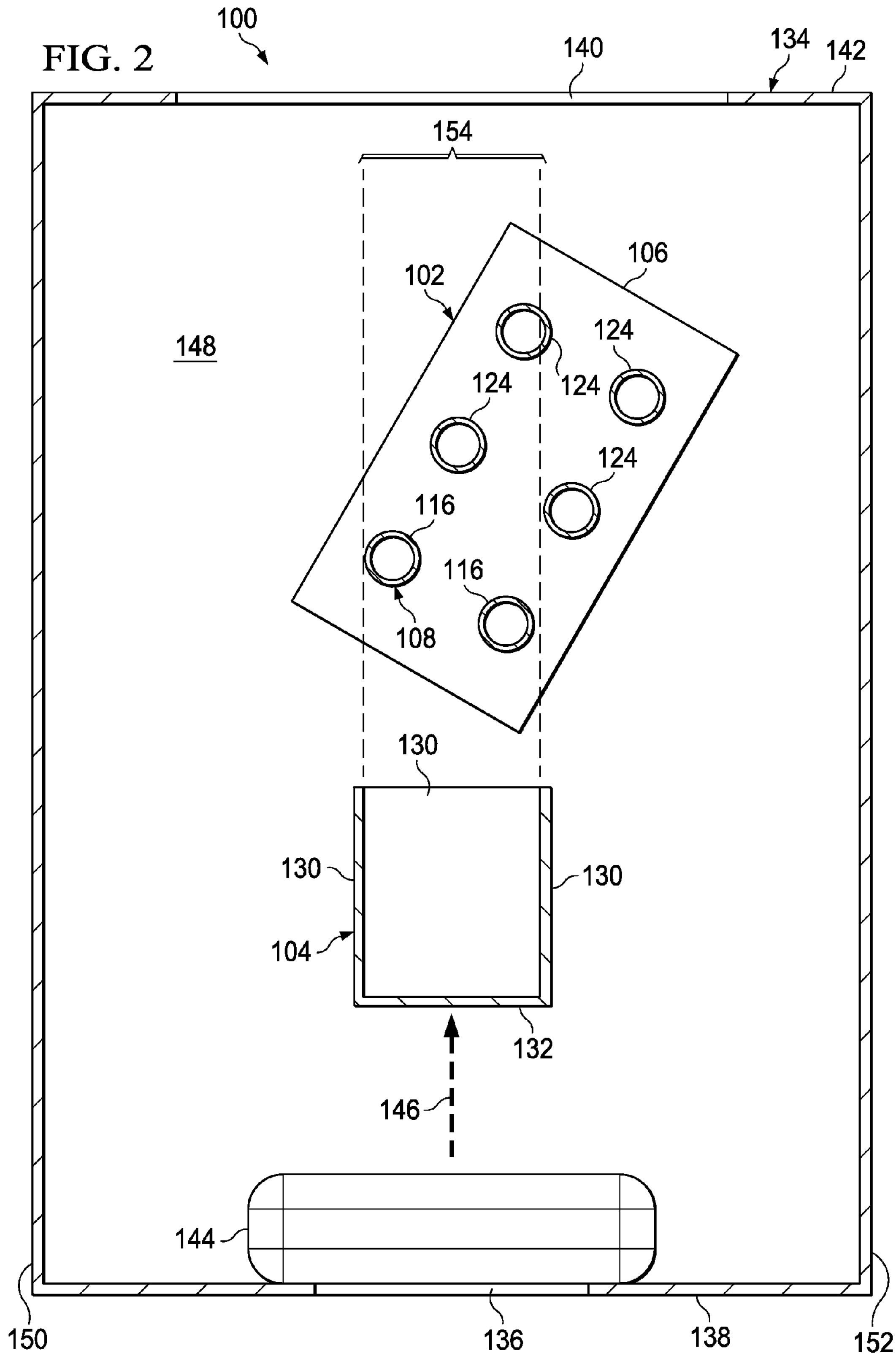
FIG. 1

FIG. 2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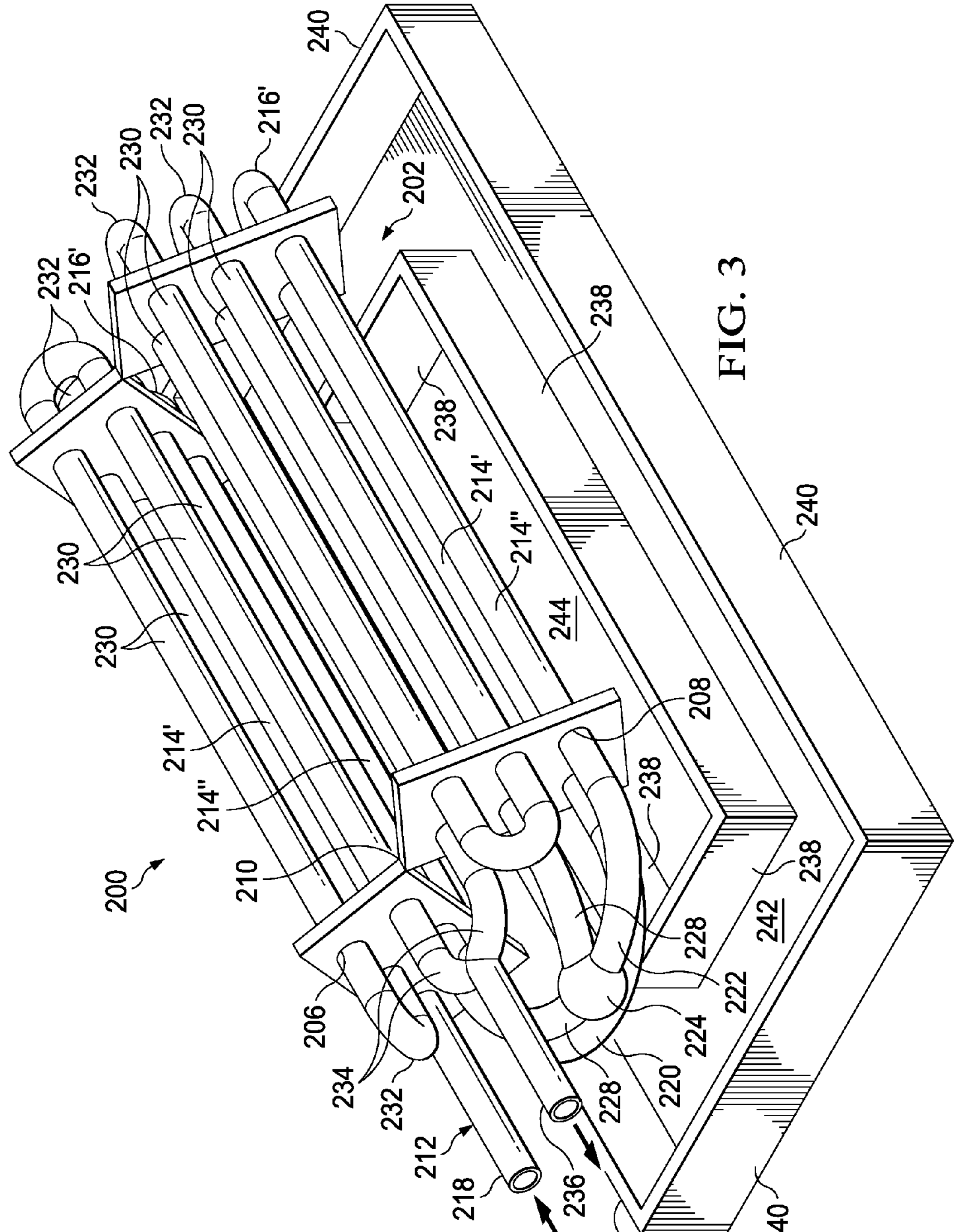
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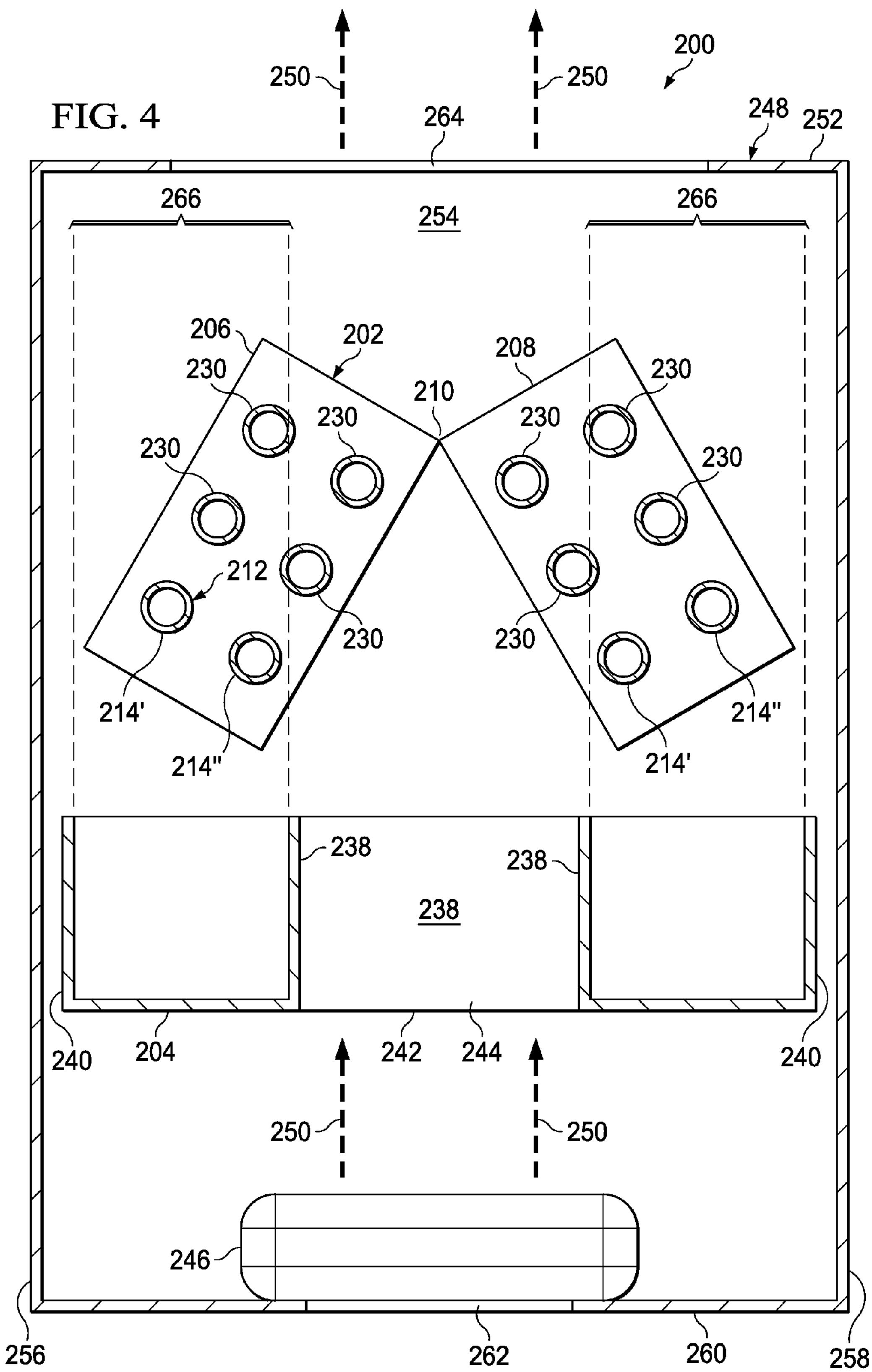
FIG. 3

FIG. 4



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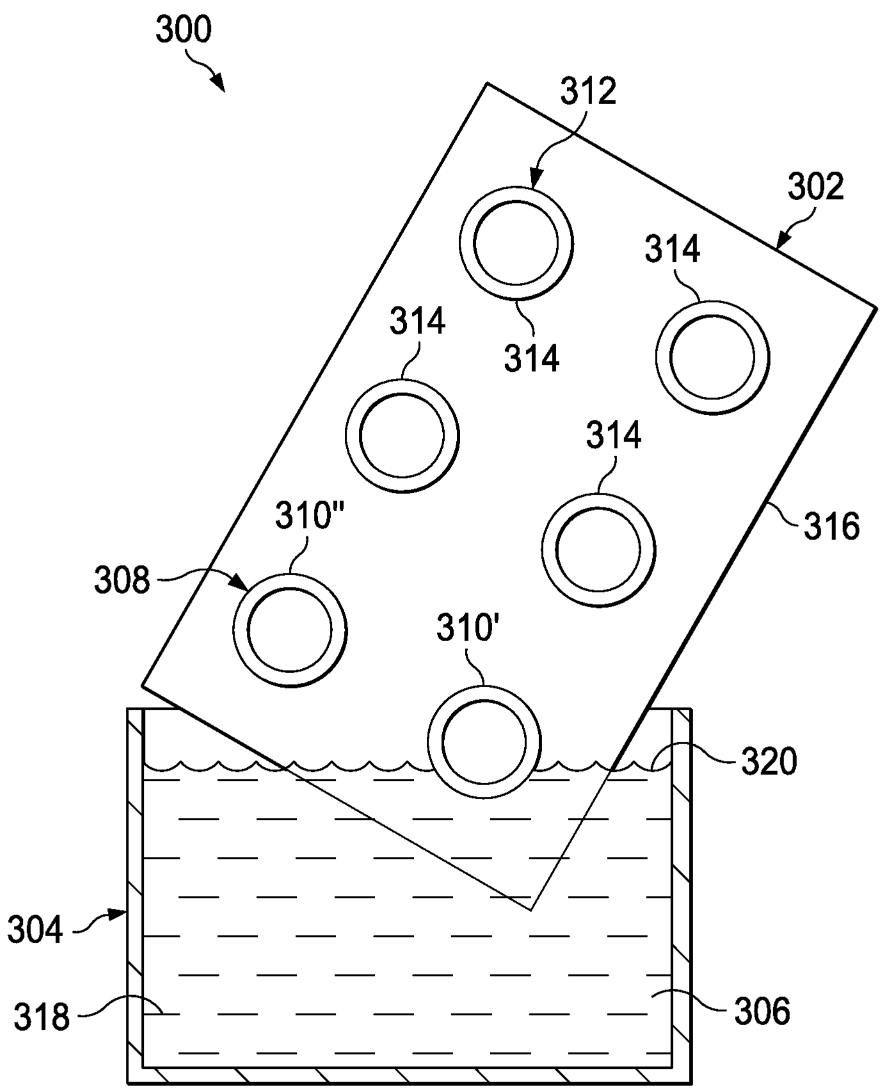

FIG. 5

HEAT EXCHANGER WITH SUBCOOLING CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

REFERENCE TO A MICROFICHE APPENDIX

Not applicable.

BACKGROUND

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) defines several tests for heating, ventilation, and air conditioning (HVAC) systems designed to mimic real-world conditions. The tests are specified in "AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Condition and Air-Source Heat Pump Equipment," which is herein incorporated by reference. Of particular interest are two tests for two-speed or variable-speed compressors—the "A" test and the "F" test. The "A" test is a test conducted at a high compressor capacity with 95° F. air entering the outdoor unit, and the "F" test is a test conducted at a low compressor capacity with 67° F. air entering the outdoor unit. These tests are directed to so-called split HVAC systems comprising an indoor unit and an outdoor unit. These tests represent relatively extreme operating conditions for an HVAC cooling system.

One way to achieve a high Energy Efficiency Ratio (EER) and thereby affecting the Seasonal Energy Efficiency Ratio (SEER) rating for an HVAC system in the AHRI "A" test is to optimize charge for the "A" test. However, as a result of optimizing charge according to the "A" test, there may be a significant loss of subcooling in the AHRI "F" test. Conventionally, in order to remedy this, additional charge may be added to achieve sufficient subcooling for the "F" test. Adding this additional charge to provide sufficient performance for the "F" test presents a problem for the "A" test because charge is no longer optimized for the "A" test and the EER at the "A" test is accordingly decreased. The "A" and "F" tests can thus place competing demands on an HVAC system.

SUMMARY OF THE DISCLOSURE

In some embodiments, an air handling unit is disclosed as comprising a blower configured to selectively move air from an air inlet of the air handling unit to an air outlet of the air handling unit along an airflow direction extending from the blower to the air outlet and a heat exchanger disposed within the air handling unit between the inlet and the outlet. The heat exchanger may comprise a thermal conductor, at least one evaporator tube thermally conductively joined to the thermal conductor, and at least one subcooler tube thermally conductively joined to the thermal conductor. The air handling unit may further comprise an expansion device providing fluid communication between at least one evaporator tube and at least one subcooler tube and a drain pan disposed within the air handling unit upstream relative to at least one subcooler tube and positioned in a geometrical footprint of at least a

portion of the drain pan as the drain pan is viewed from an upstream position in the airflow direction.

In some embodiments, an HVAC system comprising a heat exchanger comprising a thermal conductor, at least one evaporator tube thermally conductively joined to the thermal conductor, and at least one subcooler tube thermally conductively joined to the thermal conductor is disclosed. The HVAC system may further comprise an expansion device providing fluid communication between at least one evaporator tube and at least one subcooler tube and a drain pan comprising a concavity configured to receive condensate from the heat exchanger when the concavity is generally open in a vertically upward direction, wherein at least a portion of at least one of at least one subcooler tube and the thermal conductor is received within the concavity.

In some embodiments, a method of assembling an air handling unit is disclosed. The method may comprise providing a heat exchanger, the heat exchanger comprising a thermal conductor, at least one evaporator tube thermally conductively joined to the thermal conductor, and at least one subcooler tube thermally conductively joined to the thermal conductor. The heat exchanger may further comprise an expansion device providing fluid communication between at least one evaporator tube and at least one subcooler tube. The method may further comprise mounting a housing in a surrounding relationship to said heat exchanger, the housing comprising an air inlet and an air outlet, providing a blower within the housing positioned to move air from the air inlet to the air outlet of the housing along an airflow direction extending from the blower to the air outlet, and positioning a drain pan within the housing upstream relative to at least one subcooler tube so that at least one subcooler tube lies in a geometrical footprint of at least a portion of the drain pan as the drain pan is viewed from an upstream position in the airflow direction.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts.

FIG. **1** is a partial oblique view of an air handling unit according to an embodiment of the disclosure;

FIG. **2** is a simplified schematic cross-sectional view of the air handling unit of FIG. **1**;

FIG. **3** is a partial oblique view of an air handling unit according to another embodiment of the disclosure;

FIG. **4** is a simplified schematic cross-sectional view of the air handling unit of FIG. **3**; and

FIG. **5** is a partial oblique view of an air handling unit according to still another embodiment of the disclosure.

DETAILED DESCRIPTION

Some embodiments presented in this application may be directed to air handling units and/or evaporators of HVAC and/or refrigeration units. Some embodiments comprise features and/or components that may improve a performance balance between the competing demands of the "A" and "F" tests. In other words, some embodiments may not only provide efficiency at higher ambient outdoor temperatures but also provide sufficient subcooling at lower ambient outdoor temperatures. Some embodiments may accomplish this objective by trading some conventional cooling capacity of an indoor heat exchanger (or evaporator) for subcooling capability. Some embodiments may also be directed to methods of manufacturing HVAC components configured to perform in the above-described manner.

Referring now to FIG. **1**, a partial oblique view of an air handling unit **100** is shown. Most generally, the air handling unit **100** comprises a heat exchanger **102** and a drain pan **104**. The air handling unit **100** may be configured for use in an indoor unit of a split HVAC system. The heat exchanger **102** is configured to receive a substance, such as refrigerant, that may facilitate heat transfer in an HVAC system. Most generally, the heat exchanger **102** comprises opposing end plates **106** that at least partially carry a subcooling circuit **108**, an evaporator circuit **110**, and a refrigerant expansion device **112**.

In some embodiments, the subcooling circuit **108** may comprise a subcooler inlet **114** configured to receive refrigerant into the subcooling circuit **108**. The subcooling circuit **108** may further comprise one or more substantially straight subcooler tubes **116** that may be connected by one or more subcooler hairpin joints **118** (alternatively referred to as U-tubes or U-joints). The subcooling circuit **108** further comprises a subcooler outlet **120** configured to allow passage of refrigerant out of the subcooling circuit **108**. It will be appreciated that while the above-described subcooler inlet **114** and subcooler outlet **120** inherently indicate a direction of refrigerant flow in a direction through the subcooling circuit **108** from the subcooler inlet **114** to the subcooler outlet **120**, in some embodiments, refrigerant flow may occur in a reverse direction.

In some embodiments, the evaporation circuit **110** may comprise an evaporator inlet **122** configured to receive refrigerant into the evaporation circuit **110**. The evaporation circuit **110** may further comprise one or more substantially straight evaporator tubes **124** that may be connected by one or more evaporator hairpin joints **126** (alternatively referred to as U-tubes or U-joints). The evaporation circuit **110** further comprises an evaporator outlet **128** configured to allow passage of refrigerant out of the evaporation circuit **110**. It will be appreciated that while the above-described evaporator inlet **122** and evaporator outlet **128** inherently indicate a direction of refrigerant flow in a direction through the evaporation circuit **110** from the evaporator inlet **122** to the evaporator outlet **128**, in some embodiments, refrigerant flow may occur in a reverse direction.

The expansion device **112** may be a thermal expansion valve or an electronic expansion valve or an orifice or any other means of creating pressure drop and 'expanding' refrigerant from high to low pressure. The expansion device **112** may control an amount of refrigerant passing through the expansion device **112** and may cause a refrigerant pressure drop as measured across the expansion device **112**. In this embodiment, the expansion device **112** is disposed between and is in fluid communication with the subcooler outlet **120** and the evaporator inlet **122**. In the embodiment of FIG. **1**, the expansion device **112** is shown as being disposed between one half of a subcooler hairpin joint **118** and one half of an evaporator hairpin joint **126**.

The drain pan **104** may comprise a substantially open box-shaped structure. Specifically, the drain pan **104** may comprise four rectangular side walls **130** and a rectangular bottom wall **132**. As such, the drain pan may be configured to receive at least some condensate formed on the heat exchanger **102** during operation of the heat exchanger **102**. In alternative embodiments, the drain pan **104** may comprise any other suitable shape that is configured to receive condensate formed on the heat exchanger **102** and drained into drain pan **104**.

In operation of the air handling unit **100**, refrigerant may first enter the heat exchanger **102** through subcooler inlet **114** and travel successively through the straight subcooler tubes **116** and associated subcooler hairpin joints **118** before reaching the subcooler outlet **120**. Refrigerant may exit the subcooler outlet **120** and enter the expansion device **112**. As refrigerant passes through the expansion device **112**, refrigerant may encounter a fluid flow restriction that causes a change in pressure of the refrigerant prior to the refrigerant exiting the expansion device **112**. Accordingly, the reduced pressure and/or expanded refrigerant may thereafter exit the expansion device **112** and enter evaporator inlet **122**. Refrigerant may then travel successively through the straight evaporator tubes **124** and associated evaporator hairpin joints **126** before reaching the evaporator outlet **128**. Refrigerant may ultimately exit the heat exchanger **102** through evaporator output **128**. While the embodiment described above discloses inclusion of a plurality of straight subcooler tubes **116** and straight evaporator tubes **124**, other embodiments may comprise as few as one straight subcooler tube **116** and straight evaporator tube **124** connected via an expansion device **112**. This disclosure also contemplates that the subcooling circuit **108** and the evaporation circuit **110** may comprise any other suitably shaped tubes and/or joints.

In some embodiments, the end plates **106** may be constructed of metal or other relatively good thermally conductive material. In cases where the end plates **106** are constructed of relatively rigid thermally conductive material, not only do the end plates **106** maintain relative locations of the components of the subcooling circuit **108** and the evaporator circuit **110**, but the end plates **106** may be employed at least in part to also facilitate conductive heat transfer between one or more of the components of the subcooling circuit **108** and the evaporator circuit **110** as well as to facilitate convective heat transfer generally between the heat exchanger **102** and surrounding air. In alternative embodiments, one or more plate fins that are relatively thinner than end plates **106** may be disposed along the length of the straight subcooler tubes **116** and straight evaporator tubes **124** to facilitate heat transfer between the heat exchanger **102** components and the surrounding air.

Referring now to FIG. **2**, a simplified schematic cross-sectional view of the air handling unit **100** is shown. As compared to FIG. **1**, the air handling unit **100** is illustrated as further comprising a cabinet **134** substantially enveloping the heat exchanger **102** and drain pan **104**. The cabinet **134** may serve to form a fluid duct that receives air through an air inlet **136** at a bottom side **138** and expel air through an air outlet **140** at a top side **142**. The air handling unit **100** may further comprise a blower **144** configured to generate airflow in an airflow direction **146** (represented generally by an arrow). The airflow direction **146** indicates that air flows generally from the blower **144** toward the heat exchanger **102**, but that at least a portion of the drain pan **104** may prevent air from reaching the heat exchanger **102** via a substantially straight path.

The cabinet **134** further comprises a front side, a back side **148**, a left side **150**, and a right side **152**, each defined by cabinet walls. It will be appreciated that such directional descriptions are meant to assist the reader in understanding the physical orientation of the various components of the air handling unit **100**. However, such directional descriptions shall not be interpreted as limitations to the possible installation orientations of the air handling unit **100**. The cabinet walls of the air handling unit **100** substantially surround the heat exchanger **102**, drain pan **104**, and blower **144**. The drain pan **104** may be disposed in the air handling unit **100** upstream relative to at least a portion of the subcooling circuit **108**. More particularly, in some embodiments, one or more straight subcooler tubes **116** may be located downstream relative to the drain pan **104**. In some embodiments, the drain pan **104** may be described as having a downstream geometrical footprint **154** that is defined as a space within the air handling unit **100** that is generally obscured from view when viewing the drain pan **104** along the airflow direction **146** from a location upstream of the drain pan **104**. In alternative embodiments, a footprint of the drain pan **104** may be defined as a space within the air handling unit **100** to which air is not allowed to reach by traveling in a substantially straight path from the blower **144** as a result of the straight path being obstructed by the presence of the drain pan **104**. In this embodiment, at least a portion of the subcooling circuit **108** is located within the footprint **154** of the drain pan **104**. In the embodiment shown in FIG. **1**, the entirety of the subcooling circuit **108** and a plurality of components of the evaporator circuit **110** lie within the footprint **154** of the drain pan **104**. However, in alternative embodiments, more or fewer subcooling circuit **108** components and/or more or fewer evaporator circuit **110** components may lie within the footprint **154** of the drain pan **104**.

Although the blower **144** is shown on the bottom side **138** of the cabinet **134**, the blower **144** and cabinet **134** may alternatively be configured so that the blower **144** is located on the left side **150** or right side **152** to blow air from left-to-right or right-to-left, respectively, across the heat exchanger **102**. The blower **144** may be a centrifugal blower or fan comprising a blower housing, a blower impeller at least partially disposed within the blower housing, and a blower motor configured to selectively rotate the blower impeller to generate airflow. The blower **144** may comprise a variable speed motor, a multiple speed motor, and/or a single speed motor. In operation, airflow generated by the blower **144** may contact the evaporator circuit **110** to facilitate convective heat transfer between the air and the refrigerant within the evaporator circuit **110** so that the air ejected from the air handling unit **100** through outlet **140** may be relatively cooler as compared to the air entering the air handling unit **100** at the inlet **136**.

In this embodiment, some physical space of the heat exchanger **102** is allocated to receive the components of the subcooling circuit **108** instead of housing additional components of the evaporator circuit **110**. It is recognized that while some amount of cooling based on the evaporation of refrigerant within the evaporator circuit **110** may be foregone due to the above-described allocation of heat exchanger **102** space to the subcooling circuit **108**, such cooling opportunity losses may be minimized by allocating spaces of the heat exchanger **102** that experience lower velocity airflow as a result of being relatively more in the geometrical footprint **154** of the drain pan **104** than other portions of the heat exchanger **102**. Accordingly, because portions of the heat exchanger **102** that may be underutilized may include portions in the geometrical footprint **154**, those underutilized portions may be most appropriately reallocated to house components of the subcooling circuit **108**. In operation under some conditions, the subcooling circuit **108** may further cool liquid refrigerant in the subcooling circuit **108** through conductive heat transfer via the end plates **106** and/or any optionally incorporated plate fins of the heat exchanger **102**. Under some conditions, refrigerant in the subcooling circuit **108** may be cooled prior to the expansion of the refrigerant caused by the expansion device **112**. It is recognized that convective heat transfer between heat exchanger **102** and surrounding air may occur at lower rates for portions of the heat exchanger **102** that lie in the geometrical footprint **154** as compared to portions of the heat exchanger **102** outside the geometrical footprint **154**.

Referring now to FIG. **3**, an oblique partial view of an air handling unit **200** according to an alternative embodiment of the disclosure is shown. Most generally, the air handling unit **200** comprises a heat exchanger **202** and a drain pan **204**. The air handling unit **200** may be configured for use in an indoor unit of a split HVAC system. The heat exchanger **202** is configured to receive a substance, such as refrigerant, that may facilitate heat transfer in an HVAC system. Most generally, the heat exchanger **202** comprises a first slab **206** and a second slab **208** oriented relative to each other in a substantially A-shaped arrangement. Such arrangement of the first slab **206** and the second slab **208** may be referred to as an "A coil" heat exchanger because the shape of the heat exchanger **202** looks like two legs of an "A" from an end view perspective. In some embodiments, a general vertex **210** of the heat exchanger **202** is located generally further upstream in a primary airflow through the heat exchanger **202** than other portions of the heat exchanger **202**.

Portions of the slabs **206**, **208** may be adjacent, if not touching, along the vertex **210** of the A-shaped arrangement. An important difference between the A-shaped heat exchanger **202** and a conventional A coil heat exchanger is that the heat exchanger **202** has at least one built-in subcooling circuit **212** that operates substantially in a similar manner to subcooling circuit **108** as described above. Subcooling circuit **212** comprises a plurality of straight subcooler tubes **214** and subcooler hairpin joints **216**. The subcooling circuit **212** further comprises a subcooler inlet **218**, a subcooler crossover tube **220**, and a subcooler outlet **222**. A straight subcooler tube **214'** is coupled on one end to subcooler inlet **218** and on the other end to a straight subcooler tube **214"** via a subcooler hairpin joint **216'**. The remaining end of the straight subcooler tube **214"** is connected to the subcooler crossover tube **220** that delivers refrigerant from the first slab **206** portion of the subcooling circuit **212** to the portion of the subcooling circuit **212** that is built into the second slab **208**. A straight subcooler tube **214'** of the second slab **208** is connected at one end to the subcooler crossover tube **220** and at the remaining end to a straight subcooler tube **214"** of the second slab **208** via a subcooler hairpin joint **216'** of the second slab **208**. The remaining end of the straight subcooler tube **214"** is connected to the subcooler outlet **222**.

In this embodiment, the subcooler outlet **222** is connected to an input of an expansion device **224** that may simultaneously direct expanded refrigerant into two evaporation circuits **226**, one evaporation circuit **226** being located in each of the slabs **206**, **208**. Each evaporation circuit **226** comprises an evaporator input **228**, a plurality of straight evaporator tubes **230**, a plurality of evaporator hairpin joints **232**, and an evaporator outlet **234**. In some embodiments, the evaporator outlets **234** are joined in fluid communication with a singular heat exchanger outlet **236**. It is recognized that there are many different possible configurations of subcooling circuits **212** and evaporation circuits **226**. In some alternative embodiments, the heat exchanger **202** may comprise subcooling circuit **212** components in only one of the slabs **206**, **208**.

In this embodiment, the drain pan **204** comprises four inner walls **238**, four outer walls **240**, and a bottom **242**. A central opening **244** in the drain pan **204** provides an area for airflow to reach the heat exchanger **202** from a blower **246** (see FIG. **4**). In some embodiments, the drain pan **204** is configured to receive condensate that forms on the heat exchanger **202** during cooling operations.

Referring now to FIG. **4**, a simplified schematic cross-sectional view of the air handling unit **200** is shown. As compared to FIG. **3**, the air handling unit **200** is illustrated as further comprising a cabinet **248** substantially enveloping the heat exchanger **202** and drain pan **204**. The cabinet **248** and the blower **246** operate substantially similar to the cabinet **134** and the blower **144** to force air in an airflow direction **250** generally from the blower **246** toward the heat exchanger **202** through the central opening **244** of the drain pan **204**. In some embodiments, the drain pan **204** may be carried by the cabinet **248** and the heat exchanger **202** may be attached to the drain pan **204** so that the drain pan **204** supports at least part of the weight of the heat exchanger **202**. In this embodiment, at least a portion of the drain pan **204** may prevent airflow from reaching the heat exchanger **202** via a substantially straight path in much the same manner described above with regard to the embodiment of FIG. **2**.

The cabinet **248** further comprises a front side, a top side **252**, a back side **254**, a left side **256**, a right side **258**, and a bottom side **260** each defined by cabinet walls. The bottom side **260** and the top side **252** comprise an air inlet **262** and an air outlet **264**, respectively. It will be appreciated that such directional descriptions are meant to assist the reader in understanding the physical orientation of the various components of the air handling unit **200**. However, such directional descriptions shall not be interpreted as limitations to the possible installation orientations of the air handling unit **200**. The cabinet walls of the air handling unit **200** substantially surround the heat exchanger **202**, drain pan **204**, and blower **246**. The drain pan **204** may be disposed in the air handling unit **200** upstream relative to at least a portion of the subcooling circuit **212**. More particularly, in some embodiments, one or more straight subcooler tubes **214** may be located downstream relative to the drain pan **204**. In some embodiments, the drain pan **204** may be described as having a downstream geometrical footprint **266** that is defined as a space within the air handling unit **200** that is generally obscured from view when viewing the drain pan **204** along the airflow direction **250** from a location upstream of the drain pan **204**. In alternative embodiments, a footprint of the drain pan **204** may be defined as a space within the air handling unit **200** to which air is not allowed to reach a traveling in a substantially straight path from the blower **246** as a result of the straight path being obstructed by the presence of the drain pan **204**. In this embodiment, at least a portion of the subcooling circuit **212** is located within the footprint **266** of the drain pan **204**. In the embodiment shown in FIG. **4**, all of the straight subcooler tubes **214** of the subcooling circuit **212** and a plurality of components of the evaporation circuit **226** lie within the footprint **266** of the drain pan **204**. However, in alternative embodiments, more or fewer subcooling circuit **212** components and/or more or fewer evaporation circuit **226** components may lie within the footprint **266** of the drain pan **204**.

As described above, portions of slabs **206**, **208** lie in the geometrical footprint **266** of drain pan **204** and therefore may be in a lower airflow zone of the air handling unit **200** relative to portions of the heat exchanger **202** outside the footprint **266**. For the reasons described above with regard to the embodiment of FIG. **2**, because convective heat transfer between heat exchanger **202** and surrounding air may occur at a lower rate than relatively in such lower airflow zones, it makes sense to utilize such portions of the heat exchanger **202** to provide subcooling in place evaporation circuit **226** components. Accordingly, in operation, while the heat exchanger **202** may comprise a reduced capacity evaporation circuit **226**, in some operational circumstances, the heat exchanger **202** (including the subcooling circuit **212**) as a whole may provide improved performance over a substantially similar heat exchanger **202** that comprises additional evaporation circuit **226** components in place of the subcooling circuit **212** components. In some cases, the air handling unit **200** may provide improved subcooling capacity when used in HVAC systems in "F" test conditions without substantially reducing the efficiency in HVAC systems operating in "A" test conditions. For example, in a 2.5 ton HVAC system operating in a cooling mode, the use of four straight subcooler tubes **214**, two in each slab **206**, **208**, may increase subcooling from 0° F. to about 14° F. by recondensing the refrigerant with inlet air that is colder than the refrigerant temperature.

Referring now to FIG. **5**, a simplified schematic cross-sectional view of an air handling unit **300** is shown. The air handling unit **300** comprises a heat exchanger **302** and a drain pan **304**. Most generally, the drain pan **304** comprises a concavity **306** that is open in a generally upward direction. In this embodiment, a subcooling circuit **308** comprises straight subcooler tubes **310** and an evaporation circuit **312** comprises straight evaporator tubes **314**. In some embodiments, one or more of the components of the subcooling circuit **308** and the evaporation circuit **312** are carried by an end plate **316**. While in some of the embodiments described above with regard to FIGS. **1-4** provide for conductive heat transfer between the components of the subcooling circuits **108**, **212** and the evaporation circuits **110**, **226**, respectively, via end plates and/or plate fins, the embodiment of FIG. **5** further provides for conductive heat transfer between the subcooling circuit **308** and condensate **318** that may be at least temporarily held in the concavity **306** of the drain pan **304**.

In operation, condensate may form on heat exchanger **302** while the air handling unit **300** is operated in a cooling mode. Gravity may thereafter assist transport of the condensate from a surface of the heat exchanger **302** to the concavity **306**. As condensate **318** gathers in the drain pan **304**, a condensate level **320** may rise. In cases where the condensate level **320** rises sufficiently so that condensate **318** at least partially envelopes a portion of the end plate **316** and at least a portion of the subcooling circuit **308**, the cool condensate **318** may serve as a heat sink to which heat from the refrigerant in the subcooling circuit **308** may be directed. For example, because the straight subcooler tube **310'** itself may be in contact with the condensate **318** directly, heat may be transferred from within the straight subcooler tube **310'** to the condensate via a conduction heat transfer path comprising one or both of the straight subcooler tube **310'** itself and the adjacent portions of the end plate **316**. However, heat from within the straight subcooler tube **310"** that is conductively passed to the condensate requires a conduction heat transfer path that comprises both the straight subcooler tube **310"** itself and the adjacent portions of the end plate **316** because the straight subcooler tube **310** is not located within the concavity **306** and therefore cannot directly contact the condensate **318** pooled in the drain pan **304**. It will be appreciated that any of the above-described embodiments of air handling units may be modified to comprise an option for such conductive heat transfer between a subcooling circuit and condensate at least temporarily retained within a concavity of a drain pan. Further, because portions of the heat exchanger **302** are located within a concavity **306** of the drain pan **304**, the airflow rate across those portions of the heat exchanger **302** may be relatively lower as compared airflow rates across portions of the heat exchanger **302** located outside the concavity **306**. As explained above, it follows that locating subcooling circuit **308** components within the relatively lower airflow areas may provide the air handling unit **300** with improved subcooling capability when used in HVAC systems in "F" test conditions without substantially reducing the efficiency in HVAC systems operating in "A" test conditions.

This disclosure further contemplates a method of assembling an air handling unit. The method may be directed to assembling any of the air handling units disclosed herein. The method may comprise providing a heat exchanger, the heat exchanger comprising a thermal conductor, at least one evaporator tube thermally conductively joined to the thermal conductor, at least one subcooler tube thermally conductively joined to the thermal conductor, and an expansion device providing fluid communication between the at least one evaporator tube and the at least one subcooler tube. The method may further comprise mounting a housing in a surrounding relationship to said heat exchanger, the housing having an air inlet end and an air outlet end, providing a blower within the housing positioned to move air from the air inlet end to the air outlet end of the housing along an airflow direction extending from the blower to the air outlet end, and positioning a drain pan within the housing upstream relative to the at least one subcooler tube so that the at least one subcooler tube lies in a footprint of at least a portion of the drain pan as the drain pan is viewed from an upstream position and in the airflow direction.

Embodiments disclosed herein may be used in an indoor heat exchanger in a split HVAC system intended for residential or commercial buildings. Split HVAC systems are well known in the art and typically comprise an indoor heat exchanger, an outdoor heat exchanger, and a means for passing refrigerant between the heat exchangers, such as pipes, conduit, or other type of tubular connections. Although the AHRI "A" and "F" tests described earlier refer to systems that employ either a two-speed or a variable-speed compressor, the embodiments discussed herein may also be also be used in HVAC systems with a single-speed compressor. In each of the embodiments, the number of tubes, the positioning of the apertures in the end plates and/or plate fins, the shapes of the tubes, and the heat exchange properties of the tubes, plates, and fins may be varied.

At least one embodiment is disclosed and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example, whenever a numerical range with a lower limit, RI, and an upper limit, Ru, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: R=RI+k*(Ru−RI), wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, . . . 50 percent, 51 percent, 52 percent, . . . 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention. Further, while the claims herein are provided as comprising specific dependencies, it is contemplated that any claims may depend from any other claims and that to the extent that any alternative embodiments may result from combining, integrating, and/or omitting features of the various claims and/or changing dependencies of claims, any such alternative embodiments and their equivalents are also within the scope of the disclosure.

The invention claimed is:

1. An air handling unit, comprising:

a blower configured to selectively move air from an air inlet of the air handling unit to an air outlet of the air handling unit along an airflow direction extending from the blower to the air outlet;

a heat exchanger comprising a first slab and a second slab, each slab comprising an upper end and a lower end and disposed within the air handling unit between the air inlet and the air outlet such that the upper end is located nearer the air outlet than the lower end, and each slab of the heat exchanger further comprising:

at least one thermally conductive fin;

an evaporator circuit comprising at least one evaporator tube (1) comprising an evaporator tube inlet and an evaporator tube outlet and (2) disposed through and thermally conductively joined to the at least one thermally conductive fin at the upper end of the heat exchanger; and

a subcooler circuit comprising;

a first subcooler tube comprising a subcooler tube inlet; and

a second subcooler tube joined to the first subcooler tube by a hairpin joint, the second subcooler tube comprising a subcooler tube outlet, wherein each of the first subcooler tube and the second subcooler tube are disposed through and thermally conductively joined to the at least one thermally conductive fin at the lower end of the heat exchanger;

a subcooler crossover tube that delivers refrigerant from the subcooler tube outlet of the second subcooler tube of the first slab to the subcooler tube inlet of the first subcooler tube of the second slab;

an expansion device providing fluid communication between the evaporator tube inlet of the at least one evaporator tube of the evaporator circuit of each of the first slab and the second slab and the subcooler tube outlet of the second subcooler tube of the subcooler circuit of the second slab, wherein the expansion device comprises only one inlet and the inlet is connected in fluid communication with the subcooler tube outlet of the second subcooler tube of the subcooler circuit of the second slab; and

a drain pan disposed within the air handling unit upstream relative to the heat exchanger, wherein the first subcooler tube and the second subcooler tube of the subcooler circuit of each of the first slab and the second slab is positioned in a geometrical footprint of the drain pan as the drain pan is viewed from an upstream position in the primary airflow direction.

2. The air handling unit of claim **1**, wherein the drain pan comprises a concavity configured to receive condensate from the heat exchanger when the concavity is generally open in a vertically upward direction.

3. The air handling unit of claim 2, wherein (1) at least a portion of at least one of the first subcooler tube and the second subcooler tube and (2) at least a portion of the thermally conductive fin are received within the concavity.

4. The air handling unit of claim 1, wherein the first slab and the second slab are configured in a substantially A-shaped arrangement.

5. The air handling unit of claim 1, wherein in each slab all evaporator tubes are located downstream relative to the first subcooler tube and the second subcooler tube.

6. The air handling unit of claim 5, further comprising; a housing in a surrounding relationship to the heat exchanger, wherein the drain pan is secured to the housing and the drain pan provides support for the heat exchanger.

7. The air handling unit of claim 1, wherein the drain pan is configured to prevent air from the blower from reaching at least one of the first subcooler tube and the second subcooler tube of the subcooler circuit of each of the first slab and the second slab in a substantially straight path from the blower to the subcooler tubes as a result of at least one subcooler tube of the subcooler circuit of each of the first slab and the second slab being positioned in the geometrical footprint of the drain pan.

8. An HVAC system, comprising:
- a heat exchanger comprising:
  - a first slab; and
  - a second slab;
  - wherein each of the first slab and the second slab comprise:
    - at least one thermally conductive fin;
    - an evaporator circuit comprising at least one evaporator tube (1) comprising an evaporator tube inlet and an evaporator tube outlet and (2) disposed through and thermally conductively joined to the at least one thermally conductive fin at an upper end of the heat exchanger; and
    - a subcooler circuit comprising
    - a first subcooler tube comprising a subcooler tube inlet; and
    - a second subcooler tube joined to the first subcooler tube by a hairpin joint, the second subcooler tube comprising a subcooler tube outlet wherein each of the first subcooler tube and the second subcooler tube are disposed through and thermally conductively joined to the at least one thermally conductive fin at a lower end of the heat exchanger;
- a subcooler crossover tube that delivers refrigerant from the subcooler tube outlet of the second subcooler tube of the first slab to the subcooler tube inlet of the first subcooler tube of the second slab;
- an expansion device providing fluid communication between the evaporator tube inlet of the at least one evaporator tube of the evaporator circuit of each of the first slab and the second slab and the subcooler tube outlet of the second subcooler tube of the subcooler circuit of the second slab, wherein the expansion device comprises only one inlet and the inlet is connected in fluid communication with the subcooler tube outlet of the second subcooler tube of the subcooler circuit of the second slab; and
- a drain pan comprising a concavity configured to receive condensate from the heat exchanger when the concavity is generally open in a vertically upward direction;
- wherein at least a portion of at least one of the first subcooler tube and the second subcooler tube of the subcooler circuit of each of the first slab and the second slab and the thermally conductive fin are received within the concavity.

9. The HVAC system of claim 8, wherein the first slab and the second slab of the heat exchanger are configured in a substantially A-shaped arrangement.

10. The HVAC system of claim 9, further comprising a housing in a surrounding relationship to the heat exchanger, wherein the drain pan is secured to the housing and the drain pan provides support for the heat exchanger.

11. The HVAC system of claim 8, wherein the drain pan is configured to prevent air from the blower from reaching at least one of the first subcooler tube and the second subcooler tube of the subcooler circuit of each of the first slab and the second slab in a substantially straight path from the blower to the subcooler tubes as a result of at least one subcooler tube of the subcooler circuit of each of the first slab and the second slab being positioned in the concavity of the drain pan.

12. A method of assembling an air handling unit, comprising:
- providing a heat exchanger, the heat exchanger comprising:
  - a first slab; and
  - a second slab, each of the first slab and the second slab comprising:
    - at least one thermally conductive fin;
    - an evaporator circuit comprising at least one evaporator tube (1) comprising an evaporator tube inlet and an evaporator tube outlet and (2) disposed through and thermally conductively joined to the at least one thermally conductive fin at an upper end of the heat exchanger;
    - a subcooler circuit comprising
    - a first subcooler tube (1) comprising a subcooler tube inlet; and
    - a second subcooler tube joined to the first subcooler tube by a hairpin joint, the second subcooler tube comprising a subcooler tube outlet disposed through and thermally conductively joined to the at least one thermally conductive fin at a lower end of the heat exchanger; and
    - an expansion device providing fluid communication between the evaporator tube inlet of the at least one evaporator tube of the evaporator circuit of each of the first slab and the second slab and the subcooler tube outlet of the at least one subcooler tube of the subcooler circuit of the second slab, wherein the expansion device comprises only one inlet and the inlet is connected in fluid communication with the subcooler tube outlet of the at least one subcooler tube of the subcooler circuit of the second slab;
- mounting a housing in a surrounding relationship to said heat exchanger, the housing comprising an air inlet and an air outlet;
- providing a blower within the housing positioned to move air from the air inlet to the air outlet of the housing along a primary airflow direction extending from the blower to the air outlet; and
- positioning a drain pan within the housing upstream relative to the subcooler circuit of the first slab and the second slab so that at least a portion of at least one of the first subcooler tube and the second subcooler tube of the subcooler circuit of each of the first slab and the second slab lies in a geometrical footprint of the drain pan as the drain pan is viewed from an upstream position in the primary airflow direction, and so that at least a portion of the evaporator circuit lies outside the geometric foot-

print of the drain pan as the drain pan is viewed from an upstream position in the primary airflow direction.

13. The method of claim **12**, wherein the first slab and the second slab of the heat exchanger are configured in a substantially A-shaped arrangement.

14. The method of claim **12**, further comprising securing the drain pan to the housing, wherein the drain pan is positioned to provide support for the heat exchanger.

15. The method of claim **12**, further comprising:

preventing air from the blower from reaching at least one of the first subcooler tube and the second subcooler tube of the subcooler circuit of each of the first slab and the second slab in a substantially straight path from the blower to the subcooler tubes.

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